AVIATION INVESTIGATION REPORT
A02P0179

ENGINE POWER LOSS – COMPONENT FAILURE

WESTERN AERIAL APPLICATIONS LTD.
EUROCOPTER SA 315B LAMA HELICOPTER C-GGHG
MCBRIDE, BRITISH COLUMBIA 20NM S
15 AUGUST 2002

Aviation Investigation Report

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Western Aerial Applications Ltd.
Eurocopter SA 315B Lama Helicopter C-GGHG
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Summary

The Eurocopter SA 315B Lama helicopter, C-GGHG, serial number 2524, was on a visual flight rules ferry flight from Mission, British Columbia, to McBride, via Kamloops, with the pilot and two passengers on board. At about 1830 Pacific daylight time,[1] 45 minutes after take-off, the passenger sitting in the left rear seat reported hearing a bang behind him. The pilot did not observe anything unusual and felt nothing abnormal in the controls. During the refuelling stop in Kamloops, the pilot inspected the helicopter and found nothing remarkable. Near Blue River, about 45 minutes after departing for McBride, the passenger once more heard the bang from the left side; again, the pilot did not experience anything unusual and continued the flight.

Between Valemount and McBride, at about 6000 feet above sea level, the helicopter yawed briskly to the right, followed by a loud bang and a "woof" sound. The pilot lowered the collective lever to enter autorotation, confirmed that the engine had stopped, turned the helicopter to a suitable landing site, and carried out a run-on landing with low rotor rpm. The helicopter landed hard, the rear passenger seat broke, and the passengers suffered minor injuries. The helicopter remained upright, and no fire occurred. Visual meteorological conditions existed at the time of the accident, and the emergency locator transmitter activated at impact.

Ce rapport est également disponible en français.

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[1] All times are Pacific daylight time (Coordinated Universal Time minus seven hours).

Other Factual Information

The helicopter was owned by Heli-West Aviation Services Ltd. and operated under lease agreement by Western Aerial Applications Ltd. It had recently been used in heli-logging operations and other assorted transport duties generally associated with helicopter operations. This work was not unlike the type of operation being conducted by many other SA 315B Lama helicopters in the region. The wreckage was recovered and taken to Western Aerial Applications Ltd.'s facility in Chilliwack, British Columbia, where damage was documented and oil and fuel samples were taken under the supervision of Transportation Safety Board (TSB) investigators. The engine oil was found to have been contaminated with fuel, and metallic particles[2] were found on the engine magnetic detector.

The engine was an Artouste 111B1 gas turbine (serial number 1578) manufactured by Turbomeca. At the time of the accident, the engine had accumulated a total of 529.6 hours of service since last overhaul. The engine was disassembled and examined at the operator's facility under the supervision of TSB investigators, with assistance from engine specialists from Turbomeca, who provided technical expertise and tooling. (See Appendix A.)

Examination of the engine components revealed that the fuel injection tube had fractured into three sections (see Photo 1). Both fractures occurred at a change in cross-section created by a brazed-on sleeve. Most of the fracture surfaces were obliterated by component rubbing after separation. The fuel tube was scored radially at various points along its length.

The splines on the axial compressor forward coupling sleeve (part number 0218997020) and the stub shaft[3] (part number 0218150020) were found stripped and no longer capable of providing drive connection between the axial compressor rotor shaft and the reduction gearbox (see Photo 2).

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[2] Metallic particles >95% Fe (iron).

[3] The *Turbomeca Artouste III Maintenance Spare Parts Catalogue*, shown in Appendix B, refers to the stub shaft as a "sleeve."

The components were sent to the TSB Engineering Laboratory for metallurgical analysis. The examinations revealed that the forward coupling sleeve may not have received the correct heat treatment. The hardness values throughout the coupling sleeve were well below those stated in the applicable drawings and specifications. The nitriding of the sleeve was also found to be below manufacturer's specifications in some areas, but the specific area where the sleeve failed was within specifications. Fatigue cracks at the root of the coupling sleeve splines were revealed during analysis at the TSB. There was evidence of wearing of the sleeve splines, and the wear was not symmetrical on the failed parts. There was a step in the broken splines. The splines were stripped all around, but there remained a section of splines where the serrated washer "took up the gap" with evident wear and a stepped fracture toward the stub shaft side, suggesting that the failure occurred in progressive stages. Turbomeca France assisted with the testing and requested a sample from the failed part for further tests. TSB staff provided a sample from the forward undamaged section of the failed coupling sleeve. Turbomeca Materials personnel subsequently produced Report No. 1585, Issue 2. The analysis also pointed out that the fuel injection tube showed some fatigue cracks.

On 19 October 1999, under work order No. 51115804, Denel Aviation Airmotive of Pretoria, South Africa, overhauled the engine that was later installed in C–GGHG.[4] Approved modifications TU [Turbomeca] Nos. 154, 158, 159 and 169 were embodied and relate to the areas of TSB interest.[5]

On 26 January 2001, Helicraft Aviation Ltd. (aircraft maintenance organization 62–03)[6] installed the engine in C–GGHG at 9023 airframe hours. The engine had 7491 hours since new, 10 203 total cycles, and zero hours since overhaul.

Both subject components undergo on-condition inspection for serviceability, meaning that their serviceability is based on their condition at inspection. If found serviceable, they may be reused at overhaul. The *Turbomeca Artouste III Maintenance Spare Parts Catalogue*, chapter 72–31, page 4, dated October 2001, lists new part numbers for both of these components, which had part numbers that were superceded. (See Appendix B.) A review of the overhaul records for engine serial number 1578 revealed that, of the failed component parts, the sleeve assembly was deemed serviceable and re-installed. Turbomeca Technical Findings, report No. AM/99/036, completed by Denel Aviation Airmotive after dismantling the engine at overhaul, did not include a record of the stub shaft (sleeve), part number 0218150020.

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4 Denel Aviation Airmotive is now known as Turbomeca Africa, operating as part of the Snecma Group.

5 TU 154–M159 Axial compressor 6.5 mm pins replaced with 7 mm pins, which implies the replacement of all 11 blades.
TU 158–M161 Reduction gear. Lubrication of drive and intermediate pinions through an oil distributor. To improve lubrication of reduction gear high-speed gear train teeth and of the drive gear front and rear bearings.
TU 159–M160 Reduction gear and compressor coupling sleeve. Axial travel reduced down to 1 mm. To prevent wear of reduction gear/compressor muff coupling splines by reducing its axial play. Inclusion of a toothed adjusting washer. Mandatorily incorporated with modification TU158–M161.
TU–169 Axial compressor shaft. Installation of a self-locking nut on shaft extremity.

6 Helicraft Aviation Ltd. was formerly known as Marignane Helicopter Services Ltd. (MHSL, aircraft maintenance organization 103–95).

The forward coupling sleeve assembly was subjected to modification TU 159, wherein a serrated washer (L.P. Front, part number 0000411420) was installed to limit the axial travel of the axial compressor forward coupling sleeve assembly to 1 mm. (See Appendix B.) This washer, systematically replaced at overhaul, was found disintegrated. The washer is serrated to mesh with the splines and is installed inside the sleeve coupling at the axial compressor side where the washer bears against a retaining stop-ring. (See Appendix B.) Its width and thickness are determined and machined to a specified dimension at overhaul.

The washer had been introduced to limit the axial travel of the stub shaft. The purpose of the washer is actually to ensure that the shaft will not travel too far and will not reach the end of the sleeve, so that longitudinal play between the surface contact area of the splines will never be excessive.

The oil reservoir was saturated and overfull with fuel and oil mixed. The groove of the coupling sleeve contained a soft, greasy residue. The metallic content of the residue was of the same steel as that of the coupling; however, the greasy portion of the residue contained a substance that was not consistent with the lubricant used in the operation. Lubricant was observed on the outer surface of the fuel injection tube support bushings and was analyzed by the Department of National Defence's Quality Engineering Test Establishment laboratory. This substance was found to resemble an anti-seize compound that had been used on re-assembly, contrary to the manufacturer's recommendations.

In part, the *Turbomeca Artouste IIIB & IIIB1 Maintenance Manual*, chapter 72–80–00, provides a recommended method of sampling the oil: spectrometric oil analysis (SOAP). The sampling procedure and frequency provide for better engine follow-up and avoid imminent damage or deterioration in progress, undetectable by standard means. The SOAP reveals the presence of microscopic particles produced by an operational anomaly in the engine lubrication system. A lubrication system can also contain larger particles, visible to the naked eye, which are trapped in the filter or on the magnetic plug. Larger particles usually imply a serious anomaly and are not always accompanied by microscopic particles detected by SOAP. The operator is instructed to wait approximately 15 minutes after engine shutdown before siphoning off a sample (about 30 cc) from the filler orifice or collecting it from the magnetic plug on the main system.

The following table identifies sampling frequencies for all variants of the Artouste 111 engine:

Condition		Sample Rate
1	Engines whose modification standard authorizes 3000 hours between overhaul (current values)	50 hours
2	Engine with fewer than 2500 hours between overhaul	25 hours
3	Engine on which the alert concentration has been reached	5 hours

Direction and specifications are also provided for warning and rejection conditions that would require engine removal. Iron in engine oil test samples is the only condition for removing an otherwise serviceable engine. In accordance with these specifications, the concentration of iron obtained from test samples would not have required the removal of engine serial number 1578. The pilot only noticed a magnetic detector light indication in the cockpit after the engine flamed out. The system was tested functional.

MHSL performed a 400 hour/T1 airframe inspection on 16 March 2002, under work order No. 1416. On 15 July 2002, about 11 flight hours later, MHSL recorded an entry in the journey logbook under work order No. 1422 for a SOAP sample that was collected on 24 June 2002 and that was received and processed by Metro Tech Systems Ltd. (a testing laboratory) on 02 July 2002. Results indicated a “moderate” concentration of low-alloy steel wear and abnormal fuel dilution (viscosity test showing the presence of fuel in the oil). The laboratory noted the need to change the oil and filter and recommended a re-sampling of the oil. According to the sampling records provided, the engine oil was re-sampled on 18 July 2002, 13 flight hours later, and the sample was received for analysis on 06 August 2002; a “low to moderate” low-alloy steel wear was noticed with an instruction given to maintain routine sampling. The *Turbomeca Artouste IIIB & IIIB1 Maintenance Manual* provides instructions and formulae for calculating the concentrations and contamination rates of the oil, taking into account servicing or oil change. This determination was not considered and accounted for during testing. The laboratory personnel who tested the oil sample were not familiar with this engine manufacturer’s specific instructions and formulae to account for oil contamination and dilution rates.

The only inspection of engine oil that the pilots are required to do is to check the oil for a change in fluid level due to fuel dilution. *Turbomeca Artouste IIIB & IIIB1 Maintenance Manual*, Chapter 72–80–0, Lubrication – Routine Servicing, paragraph C, states that during each periodic inspection, a check should be made to determine whether there is fuel in the oil. The manual provides the warning that when assessing the rate of dilution, *do not breathe oil vapours*. A review of the journey logbook revealed no specific entry or discrepancies.

The *Turbomeca Artouste IIIB & IIIB1 Maintenance Manual*, chapter 72–00–10, page 301, provides instructions to the operator to check (and record) the power plant vibratory level and lists the frequency as follows:

Periodicity:

A. Every 400 hours (refer to chapter 5-10-2 page 2);
B. When an engine is installed (new or overhauled);
C. After a repair operation (especially on the rear bearing) and/or the replacement of an accessory which can affect the vibratory level of the engine (dynamo-starter); or
D. After repeated anomalies (cracks on supports, screws or nuts loosened, pipe rupture, abnormal noises, vibrations, etc.).

A review of the technical logbooks revealed that MHSL performed an engine vibration check at 9334.9 airframe hours, about 217 hours before the accident, following a 25 hour airframe inspection and the replacement of a cracked oil line. A subsequent vibration check was performed by Timberland Helicopters on 30 October 2001, at 7894.2 engine hours during a T1/T2 engine inspection under W.O.#031001, about 126 hours before the accident. Both maintenance facilities determined that the vibration results were acceptable.

Analysis

The two banging noises heard by the passenger and reported to the pilot before and after the en route stop at Kamloops did not cause the pilot to be unduly alarmed as there were no observed abnormal airframe or engine indications associated with these passenger comments. The source of these sounds has not been clearly determined, but they were likely associated with the failure of the fuel injection tube when it snapped on two different occasions. The sounds cannot be related to the slipping of the splined drive, as the pilot would have then felt some yawing effect on the controls. This is consistent with the fact that the helicopter kept flying for a while after the two bangs were heard, as the fuel tube is well contained in the centre of the driveshaft, which makes it possible for the fuel to continue flowing to the engine.

The splined drive in the forward coupling sleeve of the axial compressor failed progressively because of premature wear. The deterioration of the splined drive caused radial motion to be introduced to these parts, leading to distortion of the fuel injection tube. When the wear became significant enough, the wobble of the shaft was amplified, causing the fast-growing disruption of the fuel tube. The fatigue observed during the metallurgical analysis and the bangs heard by the passengers are indications that the fuel tube broke sometime before the engine flamed out.

The distortion broke the fuel injection tube at its supports and eventually caused fuel pressure to the engine to be lost when the forward coupling split open. At that instant, the engine flamed out. The reduction gear box also became disconnected from the engine drive, and power to the rotor system was lost, forcing the pilot to conduct an autorotation. During the descent, the rotor rpm became low, introducing a high rate of descent. The resulting hard landing caused the rear seat to break and the two passengers to sustain minor injuries.

The premature wear of the forward coupling sleeve can be attributed to various factors. Because of their symmetrical aspect, the contact marks on the sleeve and the stub shaft can be attributed to inappropriate axial trueness of the assembly, leading to a flexion or wobble during rotation of the shaft (i.e. the shaft was not lined up with the axis of the sleeve), and ultimately to the premature wear of the splines. Because of this improper positioning, the sleeve was undertaking a cyclic relative motion around the shaft, which inflicted some constraints on the washer, and ultimately the washer failed. When the washer failed, it deposited filings in the oil groove; this would have interfered with the lubrication of the splines and contributed to the deterioration and premature wear of the axial compressor forward coupling sleeve assembly. Furthermore, some of its parts then possibly wedged themselves between the splines of the stub shaft and the forward coupling, thus eventually forcing the coupling to split. This splitting was eased by the improper material hardness at manufacture. Moreover, the anti-seize compound contaminant found in the engine was likely applied during overhaul onto the fuel injection tube outer support bushings, to facilitate assembly of the engine. The compound was likely displaced during assembly and was found mixed with metallic residue that filled the sleeve coupling lubrication grooves. This contamination altered the lubrication of the splined drive assembly and contributed to its accelerated wear. Finally, fuel leaking from the broken fuel tube before the forward coupling sleeve split would have begun to mix with the oil, further reducing its lubricating properties.

The metal particles found in the two oil SOAP samples taken before the accident evidently came from parts of the splines and possibly the failed washer as well, as there was no other wear or damage found inside the engine.

Daily inspections and vibration checks did not alert the operator to anomalies with the engine and its oil system. The engine magnetic particle detector warning light only illuminated after the engine failure, during the subsequent emergency landing. Even after the pilot was alerted to a possible problem by the two separate bangs heard by one of the passengers, he was unaware of an impending engine failure; the failed components were internal and there were no associated abnormal engine readings.

The SOAP sample taken on 24 June 2002 was rated moderate when the maintenance facility was provided with the results on 02 July 2002. There was also a significant lag in time between the re-sampling of the oil on 18 July 2002, about 44 flight hours before the accident, and the delivery of the sample to the laboratory for testing. Results were provided to the maintenance facility on 06 August 2002, the same day it was tested. The SOAP did not provide an adequate warning of an operational anomaly in the engine lubrication system, in part because the oil was replaced on 16 July 2002 (13 flight hours earlier), thereby diluting the concentration. This oil change was not considered by the laboratory personnel who tested the oil sample, and no calculation was performed for concentration to account for the recent oil change. In accordance with Turbomeca allowances, the concentration of iron noted from sampling records would not have required the removal of engine serial number 1578. Furthermore, the engine time since overhaul was low, and the low-alloy steel wear reported may have been expected or considered normal.

When an engine is installed (new or overhauled), Turbomeca requires that a vibration check be performed. Neither MHSL nor the operator performed this vibration check after the initial engine installation. A vibration check was performed by Timberland Helicopters Inc. during a 200/400 hour engine inspection about 126 hours before the accident. The technical logbooks did not indicate any reported vibration associated with the engine.

Findings as to Causes and Contributing Factors

1. The forward coupling sleeve and its stub shaft in the engine drivetrain failed. As a result, the reduction gearbox driving the rotor became disconnected from the engine, forcing the pilot to conduct an autorotation.

2. The splitting of the forward coupling assembly is attributed to premature wear.

3. The premature wear was caused by a wobble of the shaft at the forward coupling sleeve, due to improper axial placement of the stub shaft into the coupling sleeve.

4. The below-specification hardness, resulting from improper heat treatment at manufacture, contributed to the premature wear.
5. The serrated adjusting washer failed and interfered with the lubrication of the drive coupling splines, thereby remarkably accelerating wear.

6. An anti-seize compound applied to the fuel injection tube outer support bushings during overhaul became displaced and combined with metallic debris to clog the coupling sleeve lubrication grooves. This contamination altered lubrication to the splined drive and contributed to accelerated wear.

7. The engine flamed out when the fuel supply through the fuel injection tube was disrupted.

8. The distortion of the fuel tube was caused by the amplitude of the vibration and the rotational flexion of the shaft, due to the fast-growing, premature wear of the splined drive.

9. During the autorotation descent, the rotor rpm was allowed to decrease, resulting in a high rate of descent and a hard landing, the rear seat breaking, and the two passengers sustaining minor injuries.

10. The sampling process and results of the spectrometric oil analysis were likely compromised. Consequently, they did not provide the operator with adequate warning of the deteriorating condition of the engine axial compressor forward coupling sleeve assembly.

Findings as to Risk

1. Overhaul instructions for the machining of the adjusting washer require that the washer be ground to a calculated thickness. There is no requirement to verify material condition by non-destructive testing after machining. The adjusting washer suffered undetected surface deterioration, which led to its disintegration.

2. No vibration check was performed following initial installation of the engine. The two subsequent engine checks performed did not provide indications of any anomaly with the engine and particularly with the subject internal component parts.

3. The magnetic particle detector did not provide the pilot with an early warning of the deteriorating engine condition.

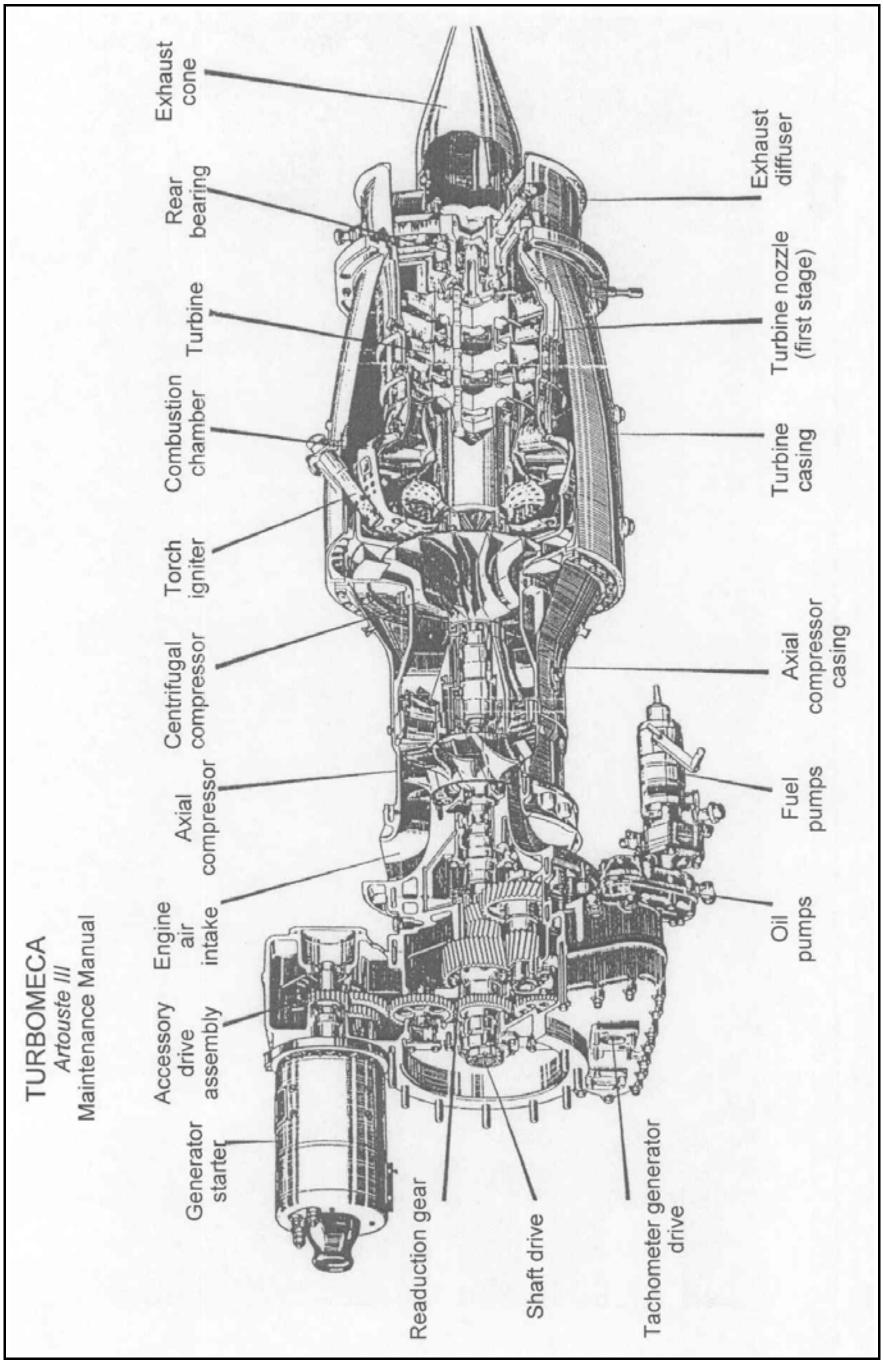
Safety Action

Turbomeca issued Alert Letter No. 2233/03/ART111/146, dated 23 April 2003, to amend vibration checks during operation. Two *Artouste III* engines that were vibration checked and subsequently disassembled at a repair centre showed traces of rubbing on the rear lips of the central labyrinth on the turbine shaft. Also noted was a slight deformation of the shaft in this area. The periodicity for engine vibration checks was reduced from 400 hours to 200 hours. Operators were notified that an update to section 72–00–10 of the Turbomeca maintenance manual was being issued. Also, Turbomeca materials personnel proposed that it would be advisable to systematically replace both sleeves (axial/reduction gearbox coupling sleeve and drive sleeve) when the drive gear to the reduction gearbox is discarded.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 09 February 2005.

Visit the Transportation Safety Board's Web site (www.tsb.gc.ca) for information about the Transportation Safety Board and its products and services. There you will also find links to other safety organizations and related sites.

Appendix A – Perspective Section of the Artouste III



Appendix B – Exploded View of the Axial Wheel and Stator